

## **A Consortium for Ocean Circulation and Climate Estimation**

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HTML link: <http://ecco-group.org/>

other sites closely linked to the project: <http://mitgcm.lcs.mit.edu/>  
<http://ecco.jpl.nasa.gov/odap/> and <http://ecco.ucsd.edu/>

### **LONG-TERM GOALS**

To bring ocean state estimation from its present experimental stage on to an operational footing in which global ocean circulation models are routinely constrained by remotely sensed and in-situ data to yield the evolving three-dimensional state of the ocean.

### **OBJECTIVES**

To develop and apply ocean circulation models and state estimation techniques in support of global ocean state estimation.

### **APPROACH**

The approach we are taking is to:

- (i) develop the MIT ocean circulation model in support of state estimation applications—improved algorithms and physical parameterizations of the forward model and maintenance and scientific application of its tangent linear and adjoint counterparts (J. Marshall and Carl Wunsch together with research scientists A. Adcroft, C. Hill and P. Heimbach, programmer D. Jamous, and student).
- (ii) explore different estimation methods, including robust control approaches (C. Wunsch and postdoc M. Losch).
- (iii) analyze and scientifically explore the ECCO state estimates (postdoc J. Scott).

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## **WORK COMPLETED**

The MITgcm that is at the heart of the ECCO data assimilation system has undergone continued improvement (Adcroft, Hill, and Marshall). The model has been documented and release 1 will be made public at the end of September 2001—see <http://mitgcm.lcs.mit.edu/>.

In Stammer et al., 2001a,b we completed first overall discussions of ECCO results including tests of estimates against withheld data. State estimates have been used to calculate global flux divergences (with S. Josey and W. Large) and energetics of the ocean circulation studied (with J. Scott). We have started exploring the use of robust control methods as a future alternative method. One student (G. Gebbie) set up an eddy resolving version of the model in the subduction experiment region to understand eddy-resolving data assimilation. Another student (X. Li), using the offline code, began constraining the model with tritium and fluorocarbon data.

We have also been involved in ‘outreach’—C. Wunsch co-directed the WOCE Young Investigator’s Workshop at NCAR.

## **RESULTS**

In collaboration with Scripps and JPL, the ECCO assimilation system has been used to demonstrate that global ocean models can be meaningfully constrained by global observations to yield an estimate of the evolving state of the ocean (see figure 1). Moreover, we have shown that the resulting state estimates are better than that which would be obtained by using either observations or models alone. These are described in two submitted papers—Stammer et al. (2001 a,b).

Four manuscripts on ECCO state estimates and their scientific interpretation were completed or nearly so. We showed a clear importance of high energy, high latitude barotropic motions to sampling and modeling the ocean.

Our future goal is to continue to improve our models and assimilation schemes and make global state estimates at higher, and eventually, eddy-resolving resolutions.

## **IMPACT/APPLICATIONS**

The impact of the ECCO project is potentially huge because it is pioneering a new way of doing oceanography. We are demonstrating that global ocean models can be meaningfully constrained by global observations to yield an estimate of the state that is better than either model or observations alone. We believe that the methods being explored in ECCO will become widely used in oceanography and change the way we observe and model the ocean.

## **TRANSITIONS**

An important part of the ECCO project is the continued development of the MITgcm to yield a widely available and used community model. MITgcm is now being used in global, regional, coastal and process study applications by a growing group of scientists. The MIT development group already has strong collaborations with JPL, Scripps, WHOI, MIT, UConn and Johns Hopkins. The public release of the model scheduled for September 2001 will make the model and its adjoint available to all. The ECCO ocean state estimates are also publically available and can be used by all.

## RELATED PROJECTS

ECCO is a close collaboration between Scripps (Professor Detlef Stammer) (<http://ecco.ucsd.edu/>), JPL (Drs. Lee Fu and Ichiro Fukumori) (<http://ecco.jpl.nasa.gov/odap>) and MIT.

The FRONTS project, led by Professor Jim O'Donnell and Dr Chris Edwards (<http://nopp.uconn.edu/>), also makes use of the models and techniques developed here.

## PUBLICATIONS

The following publications made direct use of the models developed and run with ECCO support.

Bugnion, V. and C. Hill (2001a) The climatological sensitivity of thermohaline overturning strength, an adjoint study. Part I—The idealized behavior of decadal to centennial thermohaline sensitivity, submitted to *Journal of Climate*.

Bugnion, V. and C. Hill (2001b) The climatological sensitivity of thermohaline overturning strength, an adjoint study. Part II—Thermohaline overturning sensitivity in the contemporary climate, submitted to *Journal of Climate*

Dutay, J.-C., J. Bullister, S. Doney, J. Orr, R. Najjar, K. Caldeira, J.-M. Champin, H. Drange, M. Follows, Y. Gao, N. Gruber, D. Hecht, A. Ishida, F. Joos, K. Lindsay, Madec, E. Maier-Reimer, J. Marshall, R. Matear, P. Monfray, Plattner, J. Sarmiento, R. Schlitzer, R. Slater, I. Totterdell, M.F. Weirig, Y. Yamanaka, , and A. Yool (2001) Evaluation of ocean model ventilation with CFC-11: Comparison of 13 global ocean models, to appear in *Ocean Modeling*.

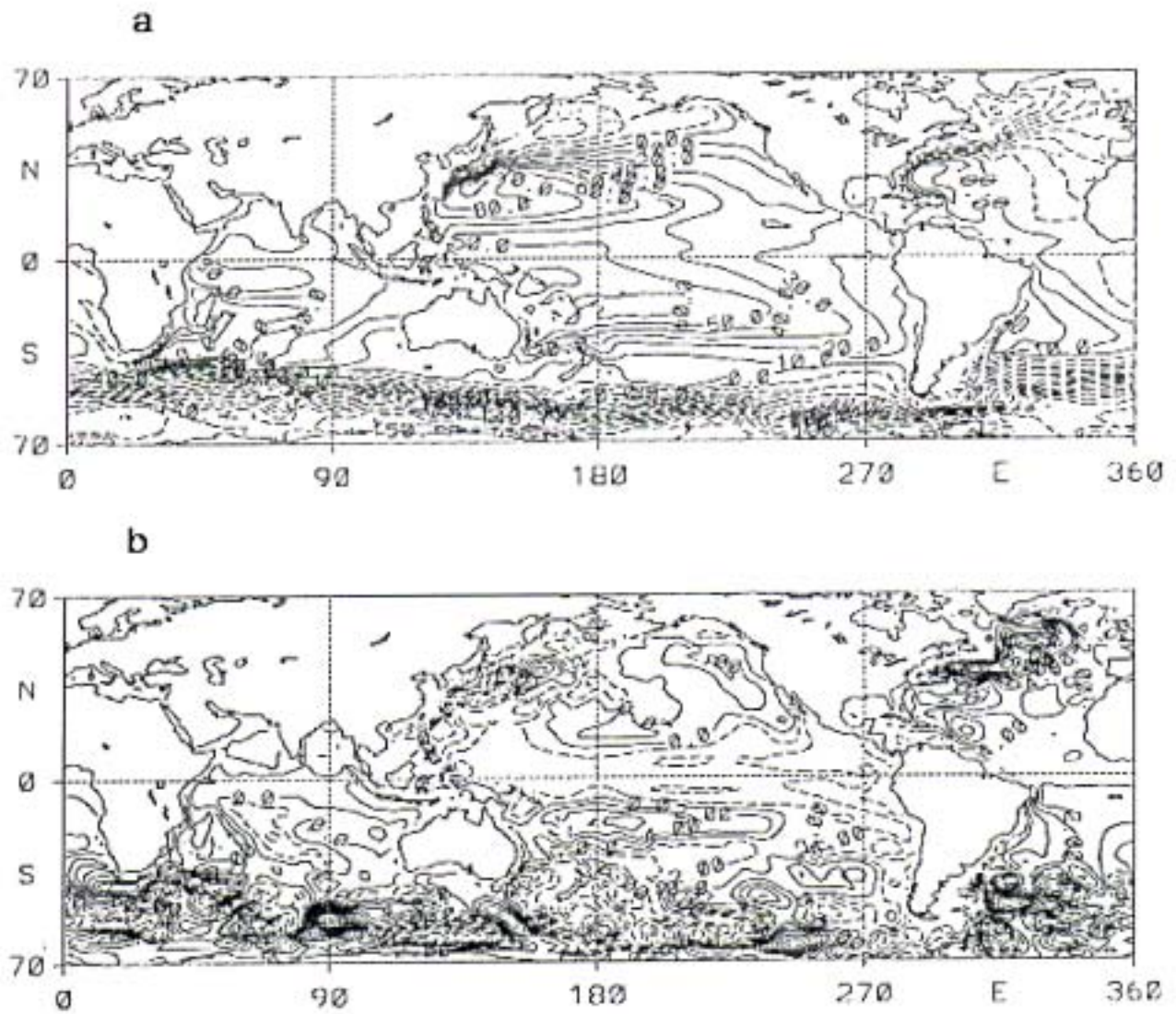
Marshall, J., J. Nilsson, and D. Jamous (2001) Entry, flux and exit of potential vorticity in ocean circulation. *J. Phys. Oceanogr.*, vol. 31, no.3, 777-789

McKinley, G., M.J. Follows, and J.C. Marshall (2000) Interannual variability of oxygen fluxes in the North Atlantic. *Geophys. Res. Lett.*, 27, 2933-2936.

Stammer, D., C. Wunsch, R. Giering, C. Eckert, P. Heimbach, J. Marotzke, A. Adcroft, C.N. Hill, and J. Marshall (2001a) Volume, heat and freshwater transports of the Global Ocean Circulation 1992–1997, estimated from a general circulation model constrained by WOCE data, submitted to *J. Geophys. Res.*

Stammer, D., C. Wunsch, R. Giering, C. Eckert, P. Heimbach, J. Marotzke, A. Adcroft, C.N. Hill, and J. Marshall (2001b) The global ocean circulation during 1992–1997, estimated from ocean observations and a general circulation model, submitted to *J. Geophys. Res.*

Wunsch, C. (2001) Oceanic age and transient tracers. Analytical and numerical solutions, submitted to *J. Geophys. Res.*



**Figure 1. (a) The time mean estimated surface elevation from the one-year period 1993. Contour interval is 10 centimeters. (b) Difference in the mean elevation fields from the optimum solution minus the model first guess. Contour interval is 2 cm.**